# Cosmic Gamma Ray Results from Explorer XI*

UNPUBLISHED PRELIMINARY DATA

W. L. Kraushaar, G. W. Clark, M. Agagino, G. Garmire, H. Helmken and P. Higbie

Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, Massachusetts, USA



The preliminary results from our Explorer XI satellite experiment were presented at the Kyoto meeting and have, together with a description of the instrument, been published elsewhere.[1,2] The instrument functioned for about seven months and the data have now been completely analyzed.

One of the most important aspects of our data is the distribution of arrival directions relative to the earth. In Fig. 1 is shown the apparent intensity as a function of $\theta$, the angle to the center of the earth. From this figure it can be seen that the earth and particularly the horizon of the earth is a strong source. There is evidence of an intensity associated with the earth out to $\alpha = 63^\circ$ above the horizon. Beyond $\alpha = 63^\circ$ the intensity is apparently uniform but this in itself does not provide assurance for a cosmic gamma ray intensity. This assurance could be provided by an established celestial anisotropy or somewhat less directly by an established absence of a geomagnetic latitude dependency. There is in our data no statistically significant celestial anisotropy. The question of geomagnetic latitude dependency happens to be technically awkward to investigate and this

* This work was supported primarily by funds provided by the National Aeronautics and Space Administration, and partly by funds from the U.S. Atomic Energy Commission.

(NASA Grant NsG-386

part of our analysis is still incomplete. With only 31 events and limited excursions in geomagnetic latitude our expectations are modest. In view of the above, the intensity implied by our data for which $\alpha > 63^{\circ}$ must be regarded as an upper limit.

The efficiency of our instrument has been measured in an effectively monoenergetic (tagged) gamma ray beam at the Synchrotron Laboratory of the California Institute of Technology. This efficiency was measured as a function of energy for the forward direction (see Fig. 2) and as a function of angle at 105 and 405 Mev (see Fig. 3). The results of these measurements have been folded with a gamma ray spectrum typical of $\pi^{\circ}$- decay (actually the spectrum measured by Svennson[3] was used) to give an effective solid angle-area-efficiency factor of $1 \pm 0.3$ cm$^2$ sterad. When this factor is applied to that portion of our data for which $\alpha > 63^{\circ}$, the corresponding upper limit to the gamma ray intensity is

$$I \geqslant (3.3 \pm 1.3) \times 10^{-4} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sterad}^{-1}$$

It should be noted that this intensity refers to the total number of $\pi^{\circ}$-decay gamma rays above zero energy. (For the spectrum assumed, only 5% have less than 40 Mev). The above value is consistent with our previously reported preliminary result.

If one assumes instead that the incident spectrum is typical of the inverse Compton effect[4] rather than $\pi^{\circ}$-decay and so has the form $KdE/E^m$, then with $m = 1.7$ the intensity upper limit is

$$I' \geqslant (3.8 \pm 1.5) \times 10^{-4} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sterad}^{-1} \qquad (E > 40 \text{ Mev})$$

and the isotropic differential energy flux at 200 Mev (the quantity used by Felton and Morrison[4]) is $(1.1 \pm 0.4) \times 10^{-3}$ Mev cm$^{-2}$ sec$^{-1}$ Mev$^{-1}$.

Our data shown on Fig. 1 may be used to deduce the approximate nature of the gamma ray emission from the earth. In this analysis the effective angular response of the instrument has been taken as the broken line on Fig. 3. We find that our data fit reasonably well a model in which the disc of the earth emits with an intensity $J = 3.2 \times 10^{-3}$ cm$^{-2}$ sec$^{-1}$ sterad$^{-1}$ and the total flux from the horizon is $F = 2.1 \times 10^{-2}$ cm$^{-2}$ sec$^{-1}$. These values were deduced, of course, from data taken at the average height of Explorer XI (about 800 km). $J$ should be independent of height, while $F$ should vary approximately as $(r^2 \cos \theta)^{-1}$ where $r$ is the distance to the earth's center and $\theta$ is the horizon angle. While the above factor is obviously not valid too close to the earth's atmosphere, it is clear that the earth-associated gamma ray flux increases greatly (much faster than $r^{-2}$) as $r$ decreases. We feel it possible that this enormous horizontal flux is responsible for the large apparent vertical flux reported by the Rochester group for their balloon-borne experiments.[5] All instruments (ours included, as in evident from Fig. 3) have some response at 90° off-axis. The contribution from this small response but huge flux does not extrapolate to zero when plotted vs atmospheric depth.

The broken line of Fig. 1 shows how well the emission properties of the earth as discussed above fit our data. In computing this curve we have included an assumed intensity from the sky equal to the value of $I$ quoted. The solid line assumes $I = 0$ but $F$ and $J$ have been increased so as to

preserve normalization. It appears unlikely that our data are consistent with this latter set of assumptions, but of course we have not and cannot now exclude other possible sources of background.

In our data analysis the sky has been divided into a number of cells, each being 1/82 of the entire celestial sphere. There were at most a few events in each cell. In many there were none. Upper limits to flux from these cells were assigned by assuming that the number of events in a given cell was one more than the number detected. Some of these cell upper limits are given below.

| | Flux upper limit |
|---|---|
| Average cell | $5.1 \times 10^{-5}$ cm$^{-2}$ sec$^{-1}$ |
| Cass A | 25. |
| M 31 | 21. |
| Cygnus A | 18. |
| Taurus A | 22. |
| Galactic Center | 16. |
| Large Magellanic Cloud | 18. |
| Small Magellanic Cloud | 19. |
| Sun | 12. |
| North Galactic Pole | 6.3 |
| South Galactic Pole | 12. |

No significance should be attached to the fact that upper limits for the various radio sources are larger than that for the average cell. The data on individual cells are of limited statistical significance, and in no

case is a measured intensity claimed.

The ratio of the intensity from the galactic plane to the intensity from the rest of the sky is $1.46 \pm 0.26$ . The ratio expected on the basis of the atomic hydrogen distribution, uniform cosmic ray density assumed, is about 3.5 .

Much of the satellite was built and engineered by the Marshall Space Flight Center. The Goddard Space Flight Center coordinated the entire project and supplied the telemetry records. It is a pleasure to acknowledge the essential cooperation with NASA personnel.

## REFERENCES

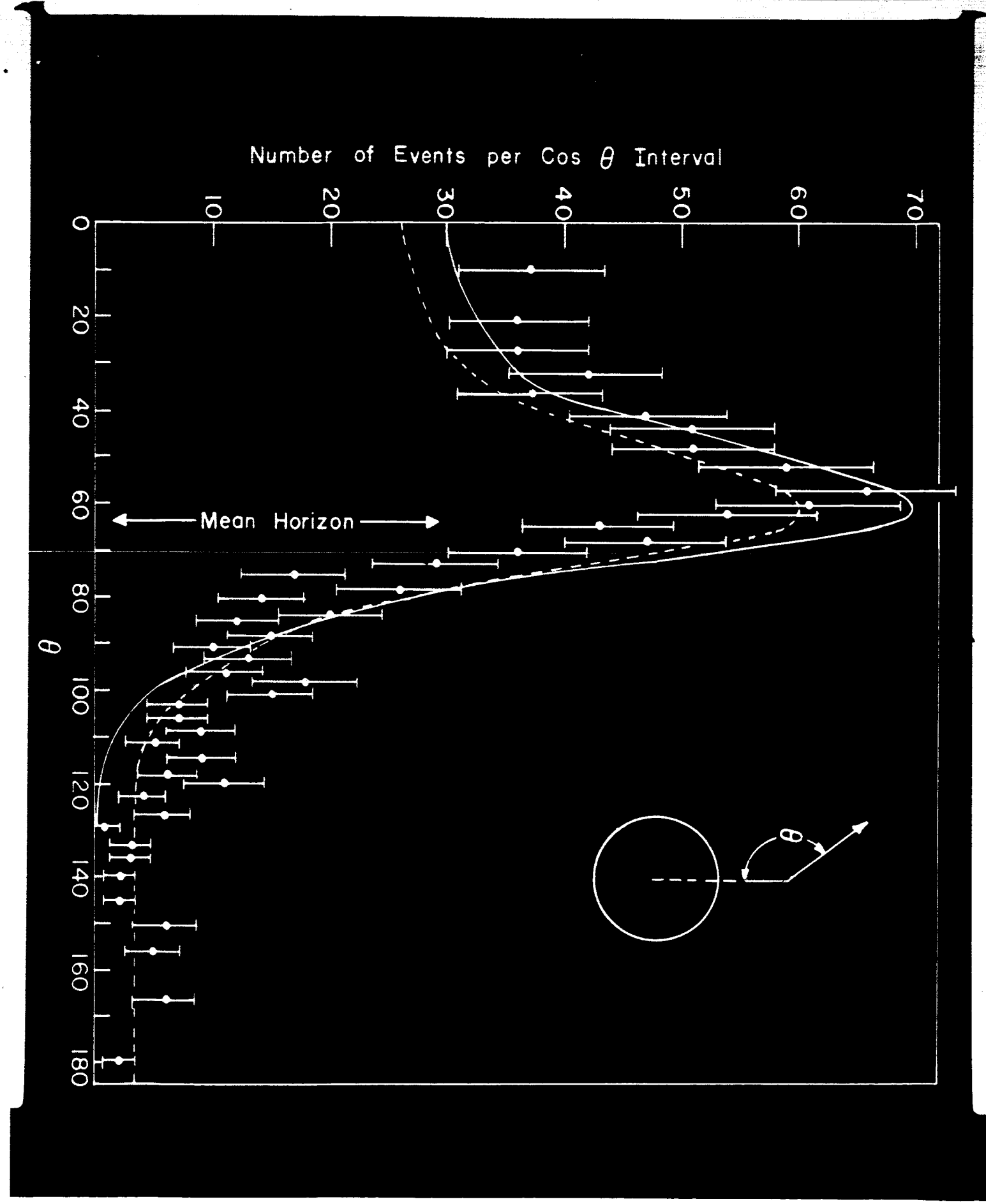
1. Kraushaar, W. L., and G. W. Clark, Jour. of Phys. Soc. Jap. 17, Supp A III 1, 1962.

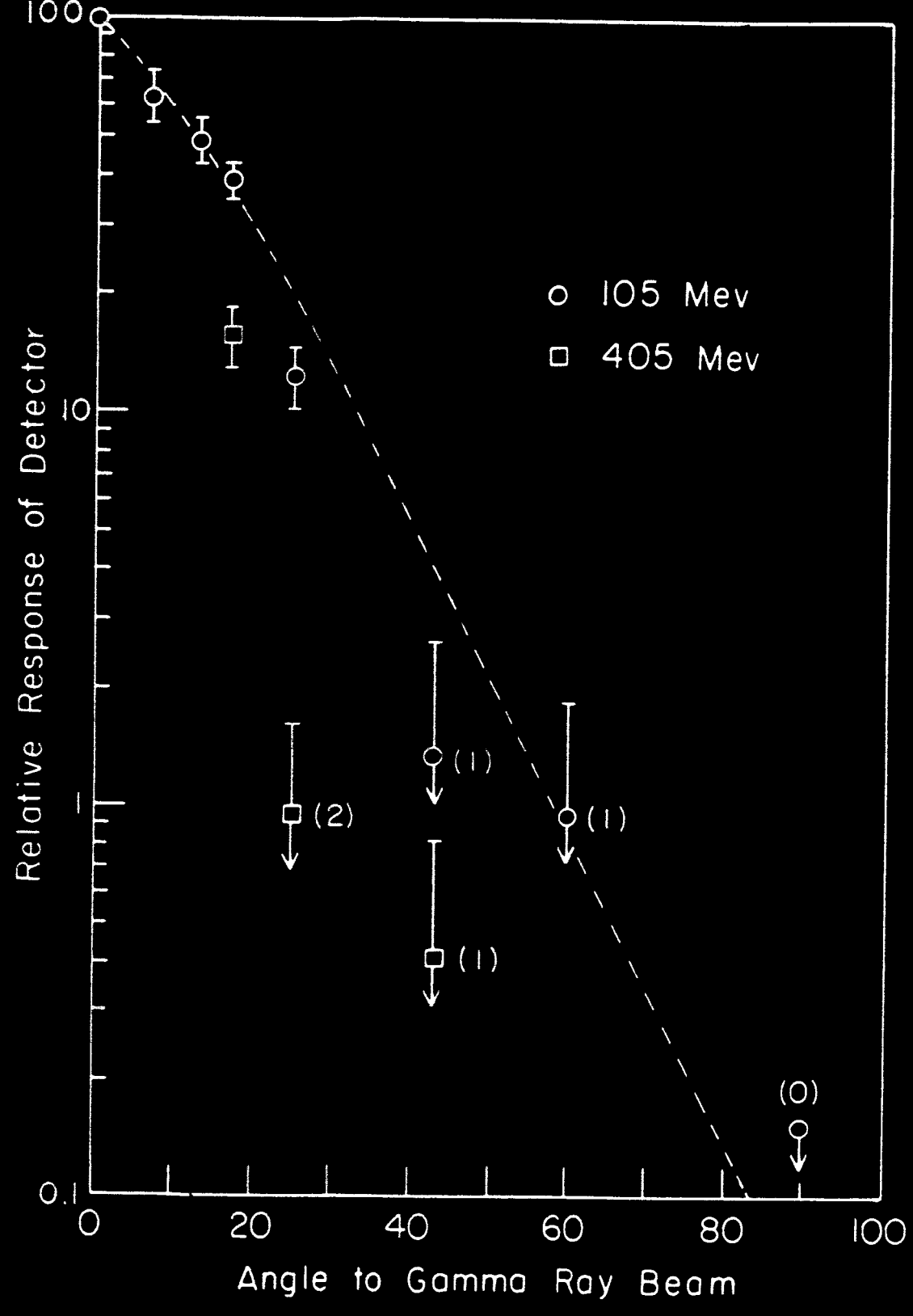
2. Kraushaar, W. L., and G. W. Clark, Phys. Rev. Letters 8, 106 (1962).

3. Svennson, G., Arkiv Fyskik 13, 347 (1958).

4. Felton, J. E. and P. Morrison, Phys. Rev. Letters 10, 453 (1963)

5. Duthie, J. G., E. M. Hafner, M. E. Kaplon and G. G. Fazio, Phys. Rev. Letters, 10, 364 (1963).


Number of Events per Cos θ Interval
10
20
30
40
50
60
70
0
20
40
60
Mean Horizon
80
θ
100
120
140
160
180
θ


100
10
0.1
Relative Response of Detector
105 Mev
405 Mev
(2)
(1)
(1)
(1)
(0)
0
20
40
60
80
100
Angle to Gamma Ray Beam